METHANOL vs ETHANOL -- '96

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The objects of this paper are:

- To review the manufacture of ethanol and methanol.
- To compare current costs of manufacture.
- To look at current use situation.
- To comment on the current government subsidies for methanol and ethanol produced from renewable resources.
- To consider the possibilities of making methanol and ethanol from various renewable resources.

METHANOL

Methanol, known as "Wood Alcohol" for generations, was initially produced as a by-product from the destructive distillation of wood. Pyroligneous liquor, from heating wood in the absence of air, contains some 4 percent methanol and 7 percent acetic acid. Thus, wood produced the majority of methanol (and other by-products such as charcoal and fuel gas) until the mid 1920's.

Synthesis of methanol directly from H2 and CO appeared in the 1920's (in some cases methanol was a step in the purification of H2/N2 mixtures on route to ammonia synthesis). Methanol is still made directly from H2 and CO, which can be made from any hydrocarbon source. At present, natural gas is the major source, however, coal, oil, solid waste, and wood can and are being used to make methanol.

Methanol use (and price) have climbed, particularly in the past few years as shown in Figure #1. Figure #1 also illustrates that MTBE has been the significant driver of methanol demand in recent years.

The overall methanol market in the U.S. is expected to continue increasing by perhaps 10% in the next four years. At the same time, because of gas limitation in the U.S., imports are projected to increase from low priced gas locations with relatively low shipping costs to the U.S.

MTBE, the major driver in the past few years, has recently suffered some setback but is expected to continue growing at a moderate rate instead of the explosive rate of 1990 through 1995. The ETBE/Ethanol situation, briefly discussed below, has and will have considerable effect on the MTBE and methanol demand.

Federal Tax Credits in the past years for so-called renewable feed based fuel and gasoline additives (currently 54¢/gal. for ethanol and 60¢ for methanol) from 1978 raised production of ethanol from 800,000 short tons to 3,500,000 short tons by 1984. The credits or subsidies boosted the uneconomic use of corn based ethanol (food to fuel) but, unfortunately, did nothing for the biomass to methanol industry which makes considerable sense in the U.S. for several reasons:

1. Biomass* is available up to a large percent of our fuel use.
2. Methanol produces the most economical fuel oxygenate, MTBE.
3. Methanol itself is an efficient, clean burning fuel. As the biomass to fuel industry develops, it will compete with gasoline with no subsidy.

*Biomass includes:
- Solid waste
- Wood
- Agricultural residues (see Table 5)

ETHANOL

Known as "Grain Alcohol" for the millennia, ethanol has been the basis of recreational beverages forever. It can be made from fruit or sugar containing materials such as

molasses. For fuel use in the USA, it is made from starchy materials such as corn, barley and sorghum. These are all renewable resources and require, for example, about 0.38 bushel of corn per gallon of 100% ethanol. There are various by-products depending upon which system is used.

The "Wet Mill" system produces by-products such as germ, gluten and a small amount of CO2. The "Dry Mill" process produces DDGS (an animal feed supplement) and a small amount of CO2. There are disagreements in the industry as to which process is most economical. Apparently, it depends largely on the return from by-products at any particular time in the overall economy.

Ethanol is also made from petroleum sources by reaction of ethylene to ethyl sulfates and then hydrolysis to crude ethyl alcohol and dilute sulfuric acid (which is then concentrated for re-use). Another process produces ethanol directly from ethylene via hydration over a catalyst.

Subsidies to the ethanol industry have resulted in rapid changes in the past 15 years. Plant capacity in 1979 of only 20 MM gallons PA became 750 MM gallons PA in 1986 and in 1994 was some 1,400 MM gallons (renewable resource based). At the same time, because of variations in the cost of grain, raw materials (approximately 45% in 1994) and apparent reduction in demand (July 1994 data show 8% reduction in demand over 1993), many U.S. Government loan guaranteed ethanol plants have had difficulty.

The dramatic changes in ethanol demand in the USA over the last 30 years are illustrated in Figure #2.

In the recent pase two things have happened to the ethanol/fuel industry:

1. The corn price has gone up from $2.75 in August 1995 to a current price of $3.90/bushel. At .38 bushels per gallon, this equals some 38¢ per gallon net increase (see Figure 9).
2. The public is at last becoming aware of the give-away of public funds by both political parties to corporations using corn uneconomically to make ethanol.

PRODUCTION COSTS

Methanol

Although methanol can be produced from various raw materials, natural gas remains the major raw material for production of methanol as illustrated in Figure #3.

This, of course, is the result of lower capital and operating costs for natural gas based methanol production versus methanol produced from other feedstocks as shown in Figure #4.

The result is that locations with low cost natural gas are able to make methanol and ship it to markets. This provides a means of using remote natural gas and shipping it to market as methanol for low polluting direct fuel use or as a raw material for MTBE (36% methanol), the leading current gasoline additive.

If it were decided to make methanol from wood, then costs might be some $200/Ton or $80.00/Ton above the cost from natural gas (approximately 25¢ per gallon above natural gas cost). Given the government tax credit of 60¢ per gallon for methanol made from sources other than petroleum, natural gas or coal, production from wood may be a very attractive option.

Ethanol

Assume corn as the feed stock and other utilities as follows:

Steam	$6.00/2000 lb. ton
Power	$0.05/KWH
Corn	$2.25/bushel [now $3.90]
By-product Sales	65% of corn cost (Wet Mill)*
	50% of corn cost (Dry Mill)*

Depreciation, Taxes, Insurance and Maintenance = 18% PA

*Assume 50% increase in by-product return with $3.90/bushel corn.

Capital costs versus plant capacity are as given in Figure #5 for methanol plants based upon conventional reforming of natural gas, wet mill ethanol process plants, and dry mill ethanol process plants. Then production costs versus plant capacity are as given in Figure #6.

Thus, methanol can be made from natural gas ($2.00 /MM BTU Gas) versus ethanol from corn ($2.25/bushel) [$3.90/bushel] for approximate prices shown in Table 1.

However, if corn based ethanol receives 54¢ per gallon credit, in the $2.25/bushel corn it is somewhat less expensive than methanol per gallon. Also, since methanol has only 73% of the heating value of ethanol, ethanol should then win hands down as a direct fuel.

On the other hand, if renewable resourced methanol were used at 78¢ per gallon with a 60¢ per gallon credit, it would compete well with 98¢ ethanol (i.e. 78 - 60 = 18¢ methanol versus 98 - 54 = 44¢ ethanol). Also, methanol is 50% oxygen versus ethanol at 34.7%. Thus, if the water separation problem with direct methanol addition is solved with other additives, oxygen addition is easier with methanol.

Both the above paragraphs are considerably changed by the current $3.90 per bushel corn price. Thus, methanol without the tax credit is clearly ahead of ethanol on price at $3.90/bushel for corn with the tax credit (see Table 1 and Figure 9).

MTBE and ETBE

Major gasoline additives containing methanol and ethanol are MTBE (Methyl Tertiary Butyl Ether) and ETBE (Ethyl Tertiary Butyl Ether).

Table 2 shows the cost of production for MTBE based on:
1. approximate cost of methanol production at 50¢ per gallon
2. current methanol market price of $.45 per gallon
3. subsidized methanol price of $.78* - .60 (tax credit) = 18¢ per gallon

*Methanol from renewable resources (biomass)

The same table also shows the production cost of ETBE based on:
1. approximate cost of ethanol production at $1.10 per gallon [1.35]*
2. subsidized price of $1.10 [1.35] - .54 (tax credit) = 56¢ per gallon [81¢]

*[ ] = based on corn at $3.90/bushel

Figure #7 is a plot of estimated production costs of MTBE and ETBE versus plant capacity showing the variation of production costs with ethanol / methanol feedstock prices. It shows relative per ton costs of MTBE (36% Methanol) and ETBE (45% ethanol). It does not show the effect of oxygen content on RFG mixtures. Oxygen contents are as follows:

Ethanol	- 34.7%
MTBE	- 18.2%
ETBE	- 15.7%

Thus, for 2.0% and 2.7% oxygen mixtures the costs per gallon of RFG are shown in Table 3 for Ethanol, ETBE and MTBE.

In spite of the above figures, which show that ethanol is by far the most economical oxygenate of these three, particularly with the U.S. Government subsidy and other State benefits, and that ETBE (with the Tax Break) and MTBE are quite competitive, the published information to date shows that marketers are choosing MTBE by some 80% to 10% with another 10% undecided. There is some indication that ethanol may be in short supply, however, prices do not show as much variation in ethanol price as has occurred in methanol, for example. Thus, a more important consideration for ethanol may be the vapor pressure effects in summer and the problems with switching from one oxygenate to another as well as the question of who makes which material and whether blenders are concerned with cost of production or market price.

US Gulf Coast market prices for MTBE and Ethanol are illustrated in Figure #8.

ENERGY USE

A brief review of the cost of energy use in the manufacture of ethanol and methanol (see Table 4) indicates that per gallon of either energy costs are similar neglecting the energy required to make corn fed into the ethanol process.

While manufacture of methanol from natural gas seems to use the least energy, methanol from wood (including the wood), costs only 40% more for energy than the dry mill ethanol system (excluding the cost of corn).

Figures prepared by the U.S. Dept. of Energy indicate that some 40 quadrillion BTU/year can be available through wood utilization in our forests. Another 4.2 quads is available from forest residues. Of this, the Department of Energy estimates that 6 quads can be captured. Other agricultural residues and municipal solid waste add up to some 4 quads for a total of some 10 quads that can be converted to ethanol or methanol.

Table 5 shows the estimated production of ethanol or methanol from these materials. The projected amounts are 54 x 10^9 gallons of ETOH in the year 2000 or 154.7 x 10^9 gallons of MEOH in the year 2000 - (equals 8.7 quads of energy). Total energy use in the U.S. in 1992 has been estimated at 82 quads.

CONCLUSIONS

1. Methanol can be made for about half the cost of ethanol per gallon.
2. More methanol than ethanol (about 3 times as much) can be made from renewable raw materials available.
3. Subsidies and loan guarantees to ethanol producers have benefited a few but by and large they have not brought about a strong ethanol based fuel sector. (Note the upset in ethanol caused by the high price of corn this year.)
4. It appears that encouraging ethanol production from corn over methanol from natural gas actually results in use of more fossil fuel for energy than if the energy were used directly. Further, it appears that methanol from wood using 16¢ worth of power per gallon will consume less fossil fuel energy than ethanol from corn (20¢/gal., excluding the energy used in growing the corn).
5. The current tax subsidy for renewable resource based methanol and MTBE, the use of wood as a feedstock may be an attractive option.
6. Use of corn to make fuel seems to be a waste. Corn is a food. It could be used to feed people in areas of the world suffering from lack of basic food.

LITERATURE CITED

1. Wood, P.R., "New ETOH Process Technology Reduces Capital and Operating Costs for Ethanol Producing Facilities", PSI, Memphis TN, *Fuel Reformulation*, July/August 1993.
2. James, G.R., P.T. Richards and W.E. Schaefer, "MEOH From Gas, Coal or Residual Oil", presented at the Asian Methanol Conference, Singapore, (1993).
3. James, G.R., B.L. Huson and P.T. Richards, "MEOH and MTBE - Their Relationships in Manufacturing and Marketing", presented at The Fertilizer Association of Indonesia Conference (APPI) (1991).
4. "21st Century Fuel News", Hart Publications, November 1994 and "Oxy Fuel News", Hart Publications, October 1994.
5. "21st Century Fuels", Hart Publications, May & June 1994, February & April 1996.
6. Kane, S. and J. Reilly, "Economics of ETOH Production in the U.S.", U.S. Dept. of Agriculture Economic Report #607, March 1989.
7. Candella, J.P., "Fuel Ethanol: Profit Margins and Product Flexibility for the Gasoline Marketer", presented at the National Conference on Fuel Ethanol, Washington, D.C. (1988).
8. U.S. Department of Energy Fact Book, 1980.
9. "Corn Fertilizer Information", Fertilizer Round Table, Atlanta, GA, 1982.
10. Unzelman, George, "U.S. Gasoline Composition: '90 Decade and Horizons", *Fuel Reformulation*, May/June 1994.
11. Singh, Margaret and Barry McNutt, "Energy and Oil Input for Producing Reformulated Gasolines", *Fuel Reformulation*, Sept./Oct. 1993.
12. Haigwood, Burl, "September/October Fuel Reformulation MTBE Survey", *Fuel Reformulation*, Sept/Oct. 1993.

13.Office of Highway Information Management; Highway Funding and Motor Fuels Division "Highway Taxes and Fees", May 1995.
14.Federal Register Vol. 60 No. 151 Rules and Regulations, August 1995.
15.Chas. A. Stokes, Sc.D, P.E., "The Methanol Industries Missed Opportunities", 1995 World MEOH Conference, Phoenix, Arizona
16.Albert J. Smith, III, Chas. A. Stokes and Peter Wilkes, "The Rebirth of Methanol From Biomas", World MEOH Conference, Atlanta, GA, November 29 - December 1, 1993.
17.Refining Economics Report, February 1996.
18.Hart's "Octane Week", April 29, 1996, Vol. XI, No. 18.

TABLE 1 CORN AT $2.25 / BUSHEL				
CAPACITY	METHANOL ¢/GAL.	ETHANOL ¢/GAL.		AVERAGE DELTA ¢
		WET MILL	DRY MILL	
500 STD	64.50	[135.00] 100.00	[140.00] 99.00	[73.00] 35.00
1000 STD	53.25	[126.00] 91.00	[133.00] 92.00	[76.20] 38.30
1500 STD	48.61	[122.00] 87.00	[130.00] 89.00	[77.40] 43.40
[@ $3.90/bushel. Includes 50% increase in by-product sales price]				

TABLE 2 MTBE and ETBE PRODUCTION COST					
				MTBE	ETBE
	PLANT CAPACITY (STD)			607	704
	Units	Unit Price	Unit Cons.	Annual Cost (1000's)	Annual Cost (1000's)
RAW MATERIALS					
Isobutylene for MTBE	Ton	$200	0.64	$25,640	
Isobutylene for ETBE	Ton	$200	0.55		$25,555
Methanol	Ton		0.364	see below	
Ethanol	Ton		0.45		see below
Catalyst	Ton	$4,550	0.00018	$164	$190
UTILITIES					
Steam	Lb	$0.006	1,000	$1,202	$1,394
Power	kwh	$0.05		$80	$93
Cooling Water	1000 gal	$0.113		$97	$113
LABOR					
Operating	MH	20.00	24,000	$480	$480
Overhead (150%)				$720	$720
REPAIR & MAINTENANCE				$698	$768
LABORATORY, SUPPLIES, & MISC.				$175	$175
TOTAL OPERATING COST				$29,256	$29,488
INTEREST (10% Debt)				$1,396	$1,536
TAXES & INSUR. (2%)				$465	$512
DEPRECIATION				$2,327	$2,560
NET PRODUCTION COST WITHOUT MEOH/ETOH				$33,445	$34,095
PRODUCTION COST / ST MTBE WITHOUT MEOH				$166.96	
PRODUCTION COST / ST ETBE WITHOUT ETOH					$146.76
PROD. COST / ST MTBE - MEOH AT $0.50 / GAL.				$221.56	
PROD. COST / ST MTBE - MEOH AT $0.45 / GAL.				$216.10	
PROD. COST / ST MTBE - MEOH AT $0.18 / GAL. (.78-.60)				$186.62	
PROD. COST / ST ETBE - ETOH AT $0.95 / GAL. [at 1.35/gal]					$276.11 [330.57]
PROD. COST / ST ETBE - ETOH AT $0.39 / GAL. (with $0.54/gal Tax Subsidy) [$0.81/gal.]					$199.86 [257.05]

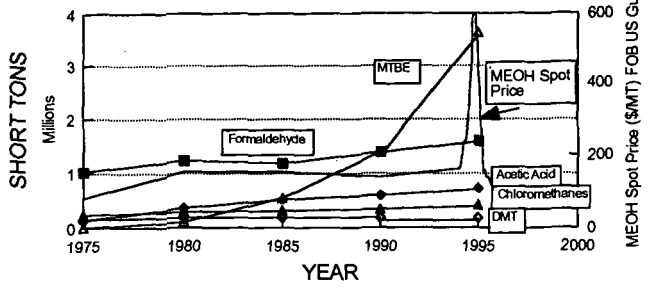
TABLE 3 CORN AT $2.25/BUSHEL		
	2% ¢/Gal.	2.7% ¢/Gal.
Ethanol - Wet Milled	[7.25] 5.24	7.08
(TB)	[4.15] (3.23)	(4.36)
Dry Milled	[7.66] 5.30	7.16
(TB)	[4.55] (3.28)	(4.44)
ETBE - (ETOH Cost)	[14.04] 11.75	15.86
(ETOH, TB)	[10.92] (8.49)	(11.46)
MTBE - (MEOH Cost)	8.12	10.95
(MEOH/TB)	(6.84)	(9.23)
TB = With Tax Break [ ] = Corn at $3.90/bushel		

TABLE 4 ENERGY COST PER GALLON OF PRODUCT			
	$/GAL.		NET CORN COSTS
Ethanol Wet Mill Steam & Power Dry Mill Steam & Power	 0.24* 0.20*	*Neglects corn use and energy required to produce it.	 30¢/gal. [52] 45.5¢/gal. [79]
Methanol From Natural Gas Natural Gas & Power From Wood	 0.186** (.178 from gas) 0.28** (.12 from wood)	**Includes Natural Gas at $2.00/MM BTU and wood at $20.00/ Ton	
[ ] = corn at $3.90/bushel			

TABLE 5 Projected Maximum Alcohol Production from U.S. Biomass Resources (Source: U.S. Department of Energy)								
	(Billions of Gallons/Year)							
	1980		1985		1990		2000	
	ETOH	MEOH	ETOH	MEOH	ETOH	MEOH	ETOH	MEOH
Wood	23.5	86.3	21.8	80.2	20.2	74.2	25.8	95.0
Agricultural residues	9.1	33.4	10.3	38.1	11.3	41.5	13.1	48.1
Grains								
Corn	2.3		2.1		0.9			
Wheat	1.2		1.4		1.6		2.0	
Grain Sorghum	0.4		0.3		0.3		0.3	
Total Grains	3.9		3.8		2.8		2.3	
Sugars								
Cane			0.2		0.7		0.7	
Sweet Sorghum			0.2		3.0		8.3	
Total Sugars			0.4		3.7		9.0	
MSW	2.2	8.6	2.3	9.2	2.5	9.9	2.9	11.6
Food Processing Waste								
Citrus	0.2		0.2		0.3		0.4	
Cheese	0.1		0.1		0.1		0.2	
All Other	0.2		0.3		0.3		0.3	
Total Processing Waste	0.5		0.6		0.7		0.9	
TOTAL	39.2	128.3	39.2	127.5	41.2	125.6	54.0	154.7
Based on following biomass-alcohol conversion factors: Wood and agric. residues-173 gal methanol per dry ton, 47 gal ethanol per dry ton. Corn-2.6gal ethanol per bushel. Wheat-2.7 gal ethanol per bushel. Grain sorghum-2.6 gal ethanol per bushel. Sugars-136 gal ethanol per ton fermentable sugars. MSW-100 gal methanol per dry ton, 25 gal ethanol per dry ton. Citrus waste-107 gal ethanol per dry ton. Cheese waste-95 gal ethanol per dry ton. Other food processing waste-90 gal ethanol per dry ton.								

Figure #1: US METHANOL CONSUMPTION

By End Products



Methanol consumption from other markets range from 0.82 - 1.35 MM short tons Per Year
Total methanol consumption in the US in 1995 approximately 8 MM short tons

Figure #2: US ETHANOL CONSUMPTION

By End Product

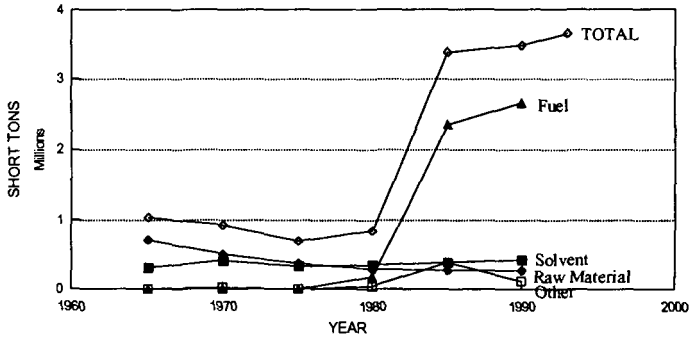
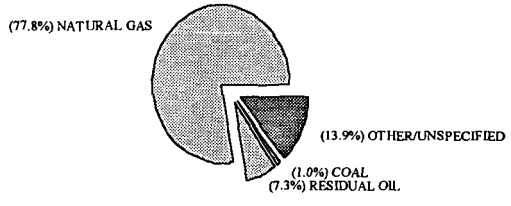


Figure 3: WORLD METHANOL PRODUCTION

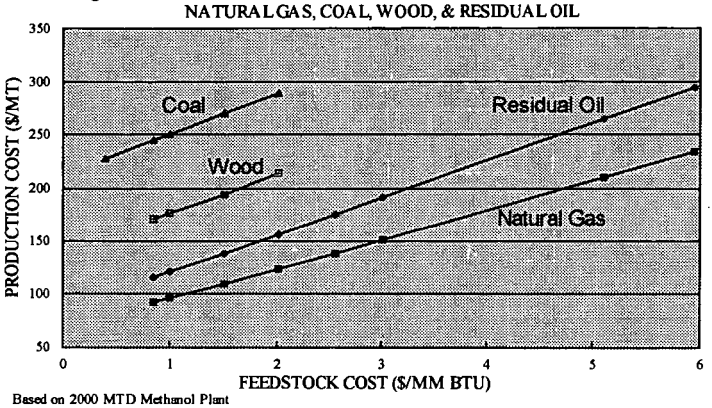
BREAKDOWN BY FEEDSTOCK



Source: Various

Figure #4: MEOH PRODUCTION COST VS. FEEDSTOCK COST

NATURAL GAS, COAL, WOOD, & RESIDUAL OIL



Based on 2000 MTD Methanol Plant
Coal - $10 to $51/MT : Oil - $5 to 35/BBL

Figure #5: PLANT CAPITAL COSTS VERSUS CAPACITY

METHANOL & ETHANOL

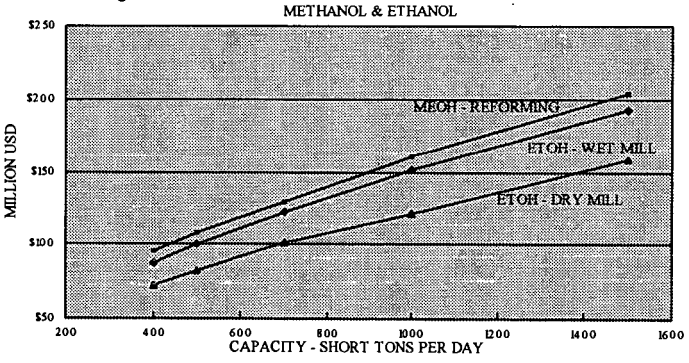
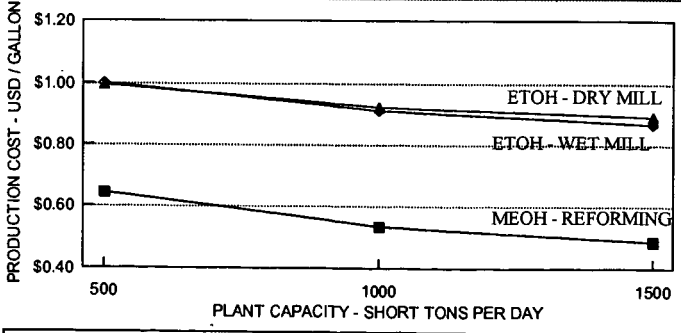


Figure #6: PRODUCTION COSTS VS PLANT CAPACITY

METHANOL & ETHANOL



Ethanol production cost based upon $2.25 per bushel corn price
See table 1 for $3.90 per bushel corn

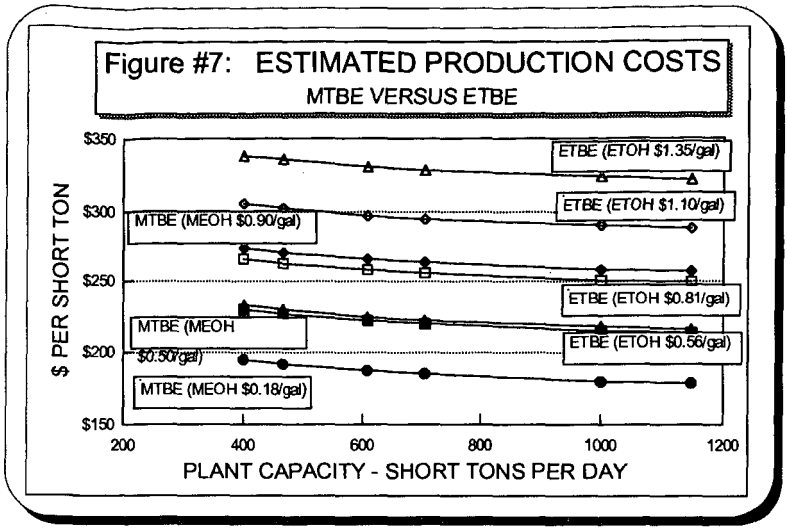


Figure #7: ESTIMATED PRODUCTION COSTS
MTBE VERSUS ETBE
$ PER SHORT TON
$350
$300
$250
$200
$150
200
400
600
800
1000
1200
PLANT CAPACITY - SHORT TONS PER DAY
ETBE (ETOH $1.35/gal)
ETBE (ETOH $1.10/gal)
MTBE (MEOH $0.90/gal)
ETBE (ETOH $0.81/gal)
MTBE (MEOH
$0.50/gal)
ETBE (ETOH $0.56/gal)
MTBE (MEOH $0.18/gal)

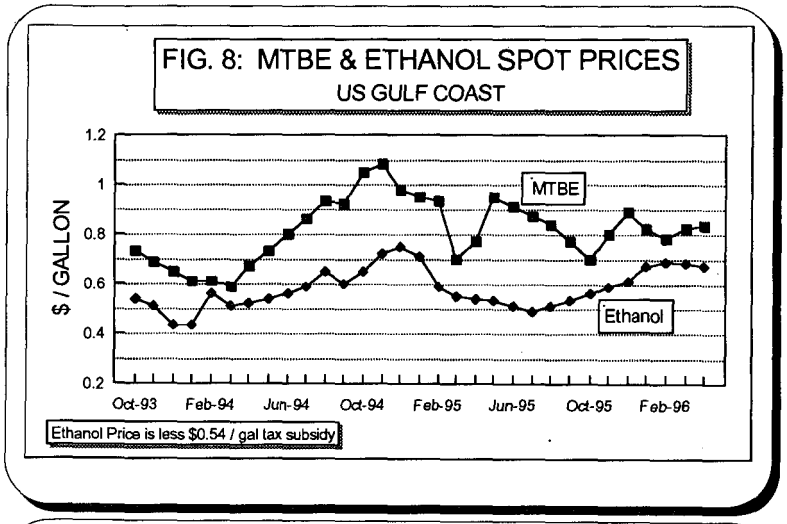


FIG. 8: MTBE & ETHANOL SPOT PRICES
US GULF COAST
$ / GALLON
1.2
1
0.8
0.6
0.4
0.2
Oct-93
Feb-94
Jun-94
Oct-94
Feb-95
Jun-95
Oct-95
Feb-96
MTBE
Ethanol
Ethanol Price is less $0.54 / gal tax subsidy

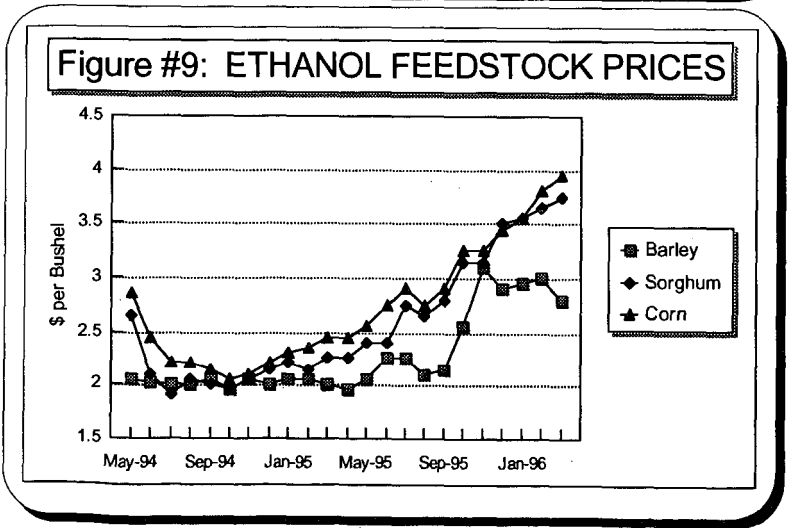


Figure #9: ETHANOL FEEDSTOCK PRICES
$ per Bushel
4.5
4
3.5
3
2.5
2
1.5
May-94
Sep-94
Jan-95
May-95
Sep-95
Jan-96
Barley
Sorghum
Corn